

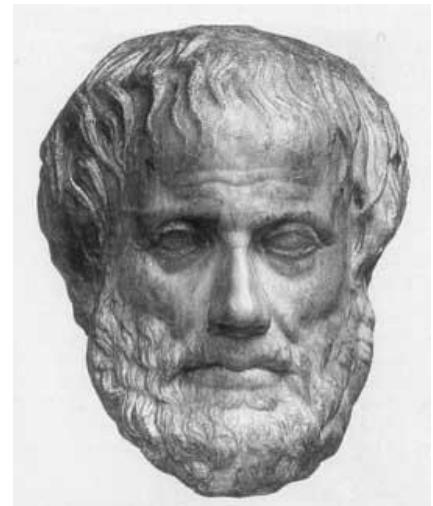
Scientific Method (General Overview)

The Scientific method was a three- step process that was contrived after formulating a hypothesis. The first step in the process was observations. The scientists derived such observations by studying in detail the environment around them. Next they formulated generalizations from these observations. Thirdly, they conducted experiments based on the generalizations. However, the experiment's outcome could only be predicted by generalizations.

The generalizations remained valid as long as they were not contradicted by the results of the experiment which was specially planned and designed to test these deductions. The conclusions were only derived from the results and observations of these experiments. Scientific laws, principles, trends etc. noted during the observations were formulated by scientific reasoning. Measurements were a key aspect of the data collected. Hence, the observations tended to be more numerical and quantifiable than subjective and qualifiable. This resulted in the scientific language evolving into mathematics.

Aristotelian Scientific method & Empiricism

Aristotle was a Greek philosopher in the BC. Times. He was the student of Plato and the teacher of Alexander the Great. He was well-versed in western philosophy and physical sciences. Through his philosophies and discoveries in science, he was the creator or introducer of the scientific method. His many contributions lay in the field of scientific enquiry. He also introduced the basis for empiricism. Empiricism is the theory of knowledge (in terms of science) that emphasizes the importance of evidence and experience etc., especially attained in the form of experimentation. Empiricism is a foundation of the scientific method as it asserts that all hypothesis must be tested against solid observations instead of intuition and reasoning.



Aristotle

Aristotle's philosophy involved the use of inductive and deductive reasoning. Aristotle felt that universal truths could be found out from particular observations or phenomenon through induction. Aristotle connected abstract ideas to observations to a certain degree. (Not all his scientific theories were empirical. Ex. His belief that earth was the centre of the universe. This is just a theory and there were no real evidence to support it. It is just a notion he came up with based on religious beliefs.) Aristotle felt that inductive reasoning was crucial to scientific enquiry and discovery but felt that scientific knowledge could not be attained by inductive reasoning. He believed that inductive reasoning was a basis for scientific experimentation.

Aristotle felt that inductive knowledge was only able to discover universal truths through the generalization of observations and that inductive knowledge was unable to build upon past known knowledge to gain new scientific knowledge. Thus, he used deductive logic to serve this purpose. Deductive reasoning is inferring conclusions from the premises supplied. The logic link between the premises and conclusion derived is not apparent and has to be figured out

through logical deductions. He specially used deductive reasoning in the form of syllogisms. A syllogism is a type of logical argument through which one proposition or conclusion is drawn from other premises in a certain form. Through syllogisms, scientists could then deduce new scientific knowledge from those already established. Aristotle developed a complete approach to scientific inquiry by involving syllogisms.

His inductive and deductive reasoning helped to form the scientific method. By integrating inductive and deductive reasoning into scientific enquiry, the observations and inferences made helped to form new scientific knowledge and improved the branch of scientific enquiry. He acknowledged that the pillars of science should be built upon solid observations and measurements.

However, there was one problem with his scientific method which lay in the premises. It was impossible to prove that the derived knowledge have solid primary premises. Aristotle did not allow that demonstrations to be circular. He did not ensure the conclusion was supported by the premises and the premises supported by the conclusion. He also did not include secondary premises between the primary premises and the conclusion. Questions arose on how Aristotle derived the primary premises. Aristotle argued that he attained the primary premises from inductive logic.

His argument caused scientists to doubt the nature and extent of Aristotle's empiricism as he only considered sense-perception as a source of knowledge. Induction was not really given crucial importance in scientific reasoning and intuition was considered as solid evidence for Aristotle's scientific ideas and theories. Despite Aristotle's greater use of intuition than solid observations and evidence, he somehow made the scientific methods from empirical than his predecessors by introducing inductive and deductive logic to scientific methods to a certain extent. His method was also the beginning of the modern scientific method, with literature reviews, consensus and basic scientific measurements.

Roger Bacon

Roger Bacon (1214–1294) was an English philosopher and a Franciscan friar. Even though he is not prominently known today, he was one of the earliest Europeans who refined the scientific methods. He was an advocate of empiricism and he built upon his predecessors' works of induction and scientific methods.

He was the one who developed the occurring scientific method cycle of making observations, formulating a hypothesis and conducting an experiment to test it. He emphasized on the need to verify results and he also documented his scientific experimentation meticulously so that other scientists could repeat his experiments as accurately and precisely as possible and verify his results. His meticulous documentation was an example to modern experimentation where the method of experimentation has to be explained in detail so that all



Roger Bacon

scientists can understand and conduct the experiments again to verify the results. In addition to this, he also touched upon the importance of inductive research.

Francis Bacon

Francis Bacon. (22 January 1561 – 9 April 1626), unlike his contemporary Galileo (who would be mentioned and elaborated on below), placed more importance on experimentation and emphasized and improvised on inductive logic in the scientific method. He was an Englishman, lawyer and a lord chancellor. He had few scientific credentials and misunderstood and disagreed with the other scientists who played a major role in the scientific revolution. However, he is still considered as the father of empiricism and experimentation.



Francis Bacon

Bacon put forth a new method of attaining knowledge. His method made a huge impact on the Royal society in England in the seventeenth century and other European scientists in the eighteenth century. Bacon believed that scientists were proceeding in the wrong direction in terms of experimentation and proposition of new scientific theories. He believed that these steps created a poor foundation of a poor scientific knowledge. He suggested that in order to create a proper foundation for human knowledge, scientific methods should be built upon inductive principles rather than assumed first principles. He fervently encouraged scientists to develop correct generalizations from organized and thorough experimentation rather than deriving logical conclusions from assumed first principles. He reiterated on the irreplaceable part that induction played in the scientific method. He improvised on Roger's cycle of scientific method by stating that in order to apply all findings to the universe, analysis

and inductive reasoning in addition to the process of scientific method must be followed.

Bacon also advised scientists and philosophers to check the validity of their scientific theories and ideas through evidence and experimentation before constructing logical speculations and theories. He also felt that experimental data could be used to eliminate inaccurate theories which conflict with the evidence found. He believed that this attempt would move humankind closer to the ultimate and accurate truth.

Bacon also disagreed vigorously with those intellectuals influenced by humanism, who believed that the "best era of humanity lay in antiquity". He felt that knowledge, specifically scientific knowledge, was needed to benefit mankind and improve human conditions. He believed that this should also be the purpose and nature of knowledge -- goal of improving sub-standard human conditions. Another belief of his is that scientific knowledge should produce useful results in terms of actions instead of words and that the pursuit of knowledge would lead to material improvement and would increase the power of governments and monarchies.

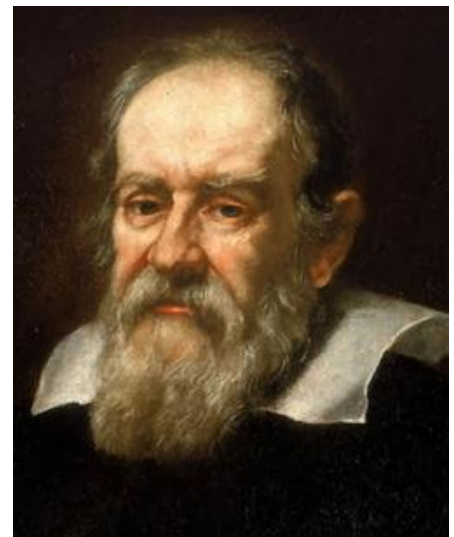
Besides his contributions to the scientific method, his other contributions were that his thoughts in the importance of scientific knowledge and the role it played in the governments' power helped to bridge the gap between governments and the scientific enterprises and his method based on evidence and experience helped to influence scientific methods which were more productive. This was so despite his method being unsystematic from induction to empirical evidence.

Nevertheless, many people feel that Bacon has been credited too highly for his contributions as they felt that he was only a natural philosopher in an amateur sense. They believed that his real accomplishment was only to set an intellectual tone for science and helping to create a conducive environment to carry out scientific work.

Galileo Galilei

Galileo Galilei (15th February 1564- 8 January 1642) was an Italian physicist, mathematician, astronomer and philosopher who was one of the major forces in the scientific revolution. He has credited to be the father of modern science and the scientific method. His major contribution to the scientific method lay in his new science of motion.

Galileo unveiled his theory of motion during the period of religious conservatism when the Reformation and counter-reformation movements were rampant. Galileo's scientific theories and scientific methods were not similar to Aristotle's ones. Aristotle believed that science should be proved through previous principles. In contrast, Galileo proved his scientific theories through experimentation; However, Galileo presented his findings specifically in terms of mathematics instead of experimental results. He standardized scientific measurements so that experimental results could be tested anywhere. He built upon Aristotle's empiricism and relied on an inductive scientific method due to his belief that no empirical evidence would be a perfect match for theoretical predictions.



Galileo Galilei

Nevertheless, it was a revolutionary and innovative step forward in terms of scientific methods. In Aristotelian times, mathematics was not seen as a tool to record down the scientific data and also to discover the causes beyond scientific phenomenon. Before Galileo's modified method, scientists did not comprehend the importance of mathematics in obtaining scientific results. Through Galileo's greater use of mathematics demonstrations in science, mathematics came to play a greater role in the scientific method.

Rene Descartes

Rene Descartes (1596-1650), a Frenchman and a great philosopher and mathematician, was another important force in terms of the scientific method. He was the first

man who attempted to apply the new methods of science to the theories of knowledge. Through this, he also laid the foundation for modern philosophy.



Rene Descartes

He realized that despite the importance of observation and experimentation, people were deceived by their senses. He realized that in order to find the sound truth, he needed to doubt the existing knowledge and that he should not accept any facts without solid evidence. The only thing he would know about theories and ideas was that he doubted them and through this, he was thinking and proving his existence as a human being. These realizations did not only contribute greatly to philosophy but it also improved the accuracy of scientific methods as he made scientists acknowledge that the scientific knowledge that was seen as a foundation for scientific methodology may not be necessarily accurate.

He also emphasized on deduction and mathematical logic which complemented Bacon's beliefs of induction and solid experimentation and observations. Descartes also stated in "Discourse on Method" that each step in an argument and scientific theory should as specific, accurate and well- proved. He also believed that in order to derive complex and well-supported conclusions, scientists should start with simple and accurate truth. This contribution also helped to refine the scientific method.

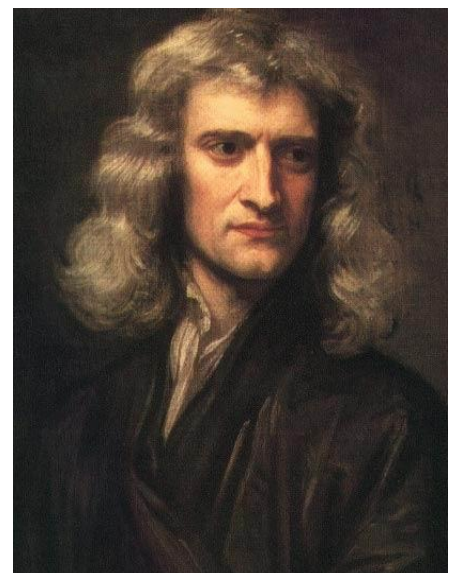
Descartes believed in being more rational than his predecessors and thus, he focused more on supporting a scientist's theory with accurate evidence than the process of formulating a theory. Thus, he was skeptical of theories with little evidence and rejected them. Through this, he improved on the scientific methodology which relied on the scientific theories.

Despite his disbelief of the Aristotelian system and ideas, many critics believe that his contribution was not really that significant and that he had only replaced Aristotle's primary theories with his own theories. Nevertheless, his rationalism was a stepping stone for Sir Isaac Newton to improve the scientific methodology.

Sir Isaac Newton

Sir Isaac Newton, (25 December 1642 – 20 March 1727) was an English physicist, mathematician, and astronomer. He was the discoverer of universal gravitation and is considered as one of the influential and prominent man in human history. He was also one of the contributors to the scientific methodology through the improvisations that he made to the previous methodology submitted by his predecessors.

He was the first man to really understand the importance of induction and deduction in the scientific methods. He also combined Bacon's empiricism with



Sir Isaac Newton

Descartes' rationalism to form a single scientific methodology to form one which was more accurate and useful. His method started off with scientific observations and experimentation which formed general concepts. These concepts would then be used to form hypothesis which would be tested and proved by experimentation.

His method was more reliable and helped to form the basis for today's scientific methodology. Without his corrections in the scientific methodology, today's science would not be accurate and reliable as there will be an ongoing confusion on whether the methodology should be more empirical or rational. Through his synthesis, he simplified scientific methodology.

Scientific methodology's acceptance in the past

The scientific methodology was helpful and successful in clarifying one's doubt on how something works. The scientific methodology inspired confidence in other scientists due to its success. The scientific methodology would have been prominent and well-used by the other scientists if not for one disadvantage of it. It did not answer the question of why something works and purpose of nature and the world. This disadvantage was exploited by religious groups and religion was still of more importance than science and its discoveries and methods in the seventeenth century.

Science methodology in the present

Since the seventeenth century, science methodology has become more important, especially due to the popularity of science in the current twenty-first century. Scientists now days consider a scientific method to be a method of inquiry that is based on observable, measurable and empirical evidence that is proof of a well-reasoned scientific theory. Data must be collected through observation and experimentation and the hypothesis formulated must be testable. The scientific method has been modified and more specific steps have been added on to it. The modern version of the scientific method is:

Step 1: Define or set a specific question or a set of questions.

Step 2: Gather information from other sources of knowledge and data that were collected

Step 3: Formulate a specific and testable hypothesis

Step 4: Perform the experiment and record down your observations and measurements as data.

Step 5: Analyze the data

Step 6: Interpret the data and draw relevant conclusions from them that could pave the ways for new hypothesis.

Step 7: Publish results

Step 8: Re- experimentation

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